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(54) Method for welding aluminium plates

(57) A method of manufacturing a structure, preferably a curved structure, for example a spherical LNG-tank or the like, of welded together metallic, e.g. aluminium, plates, comprising welding flat metallic plates means (4,5) together by downhand welding whilst supporting the plate means on a tiltable structure (12a). The angle of the tiltable structure is controlled during the welding to provide a substantially constant inclination of the welding groove throughout the welding of the plate assemblies. A structure, e.g. a spherical LNG-tank, formed by the method is also disclosed.

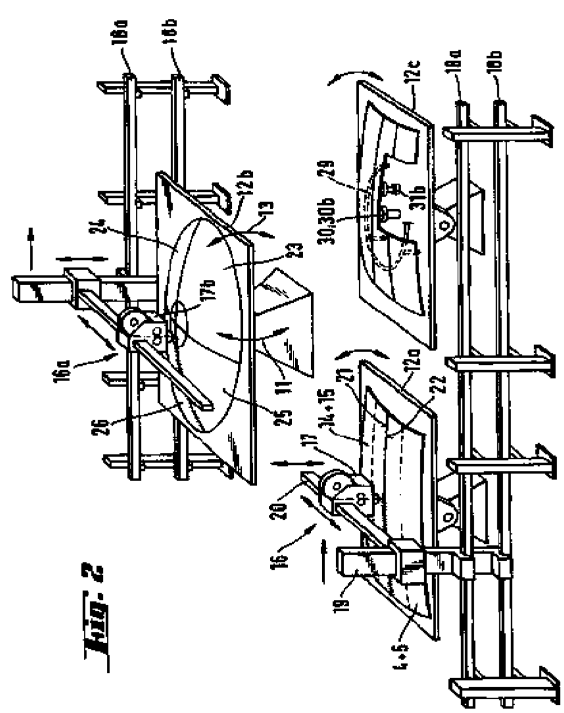

Fig. 2

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Description

This invention relates to a method according to the preamble of claim 1. In particular, but not exclusively, the invention is intended for welding together aluminium plates for manufacturing a spherical LNG-tank and to a spherical LNG-tank manufactured by this method.

The manufacture of vessel-born tanks for liquified natural gas (LNG) includes welding together large and thick aluminium plates which are shaped to form the spherical LNG-tank. Similar tanks may be used in places other than on vessels for storing LNG or other substances. Because a large proportion of the manufacturing costs are the welding costs, it is cost advantageous for the plate blanks welded together to be as large as possible. However joining together such large plate blanks and so formed welded plate assemblies by further welding is demanding work, since all the weld joints must be of high quality. Furthermore the plates and the plate assemblies must be made to a high tolerance with regard to their shape and dimension to achieve a proper final result.

EP-A-0570212 relates to the manufacture of large spherical LNG-tanks of welded together aluminium plates and discloses welding together several flat or plane plates, subsequently forming the welded plate assembly in a mould into a part-spherical shape and using the formed plate assembly in the following stage of manufacture. However, during forming of the plate assembly in the mould, the plate assembly stretches somewhat. This makes it difficult subsequently to use modern, high power, MIG-welding equipment for welding in one pass per side because there are shape defects in the welding groove and at its root.

It is also known to manufacture spherical tanks of plates which are welded together by a so-called tractor type welding carriage to form larger plate assemblies. However, difficulties and waste of time occur, especially at the start and finish of the welding process, when using this kind of equipment. Known manufacturing methods for welding preformed plates together with tractor type welding equipment also require double the number of assembly stations. Since removal of the weld reinforcement before forming is necessary because of the inspections included in many methods and because of the forming itself, special attention has to be given to the automation of the work and to the dimensional precision of the final work.

An object of the invention is to achieve a high level of automation in the manufacture of welded structures, for example curved structures such as large spherical LNG-tanks, and to improve the quality of both the welds and the manufactured structure, e.g. a spherical tank.

According to one aspect of the invention, this object is achieved by a method as claimed in the ensuing claim 1.

A large spherical LNG-tank or the like has a diameter of at least 20 metres, may be even more than 40 metres. It can be manufactured according to the invention from aluminium plates typically having a thickness of from 20 mm to 70 mm. The plates to be welded together are conveniently held in a fixed position during welding by jigs and suction fastening devices.

The plate means are suitably formed by welding plane plates together by using manipulating means mounted on an adjustable and lockable overhead frame. The manipulating means conveniently comprises, in addition to welding equipment, a device for scraping or brushing the weld groove prior to welding for removing impurities and any oxide layer on the aluminium. Removal of the oxide layer reduces the risks of subsequent welding defects. The groove brushing device moves along the weld groove in front of the welding device, most suitably at a distance of about half a metre from the welding device. The manipulating means may also be provided with cutting means, e.g. a milling cutter, for removing the weld reinforcement so that the welded joint is made substantially flush with the welded together plates. The cutter moves along the weld groove behind the welding device and removes the weld reinforcement immediately after the formation of the weld. Because the cutter is a part of the manipulating means, the repeatability of the cutting is excellent, accurate and fast.

Suitably the welded together plates forming the plate means are plasma cut to a size and shape suitable for the structure, e.g. a spherical LNG-tank, being manufactured. However a working allowance is made because the edges of the plate means for the subsequent welding stage are made by a form milling cutter. Accurate forming of the groove and the production of smooth groove surfaces are important for achieving compatible plate edge surfaces to be joined which are required for producing a good finished weld.

Two plate means bent to a curved or spherical shape are suitably joined together with a flat butt weld using a manipulator device and the tilting support structure. The curved structure, e.g. a spherical LNG-tank, to be manufactured may be assembled from large sections at the final assembly site.

The metallic, preferably aluminium, plates are conveniently welded together with the use of a manipulator device with only one pass per side irrespective of material thickness. For this purpose, a high power welding device may be used. Fastening and turning equipment is provided for turning the plate means upside down to enable both sides of a joint to be welded using a downhand welding technique. To speed up the work, it is of advantage to use a production line having the turning equipment located between two manipulator devices.

In order to weld plane plates to form larger plate means or assemblies, a suction fastening device holding the plane plates is tilted so that the groove at the welding point is inclined upwards in the welding direction by from 4° to 7°, preferably about 5°. It is then possible to use a high power welding device and to complete the weld joint on one side in one pass, because full control of the melt

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is easily achieved when the weld groove is slightly upwardly inclined.

The plate means or assemblies bent to a curved or part-spherical shape for subsequent welding together are supported on the tiltable support structure by means of which the inclination of the plate assemblies at the welding point is set to a value of from 4° to 7°, preferably about 5°, upwards in the welding direction. Since the welding groove is curved in a vertical plane, this is achieved by continuously adjusting the angle of tilt of the tiltable table during welding. This makes it possible to use high power welding equipment and to complete the weld joint on one side in one pass for the reasons mentioned above.

It is of advantage to support at least two plate means of part-spherical shape by a support device substantially in the shape of a circular ring. In this case either the convex side or the concave side of the part-spherical shape may face upwards during the welding. The circular ring should be dimensioned so that its diameter is as large as possible for achieving a good support of the plate means, but sufficiently small that the plate means totally cover it. It is also possible to use a known suction fastening device with suction heads which face the plate means and which are easily adjustable. The vertical position of the suction heads can thus be adjusted to support from below either the convex or the concave surface of the plate means.

The height of the support structure in the central region of the support assembly is adjustable depending on whether the plate means to be welded are positioned with their concave or convex sides upwards. According to a preferred embodiment, the support structure in the central region of the circular ring comprises a small circular ring with a diameter of , for example, approximately 1250 mm, the height of which is adjustable so that it supports either the convex or the concave side of the plate means. Another method of support is to provide, in the central area of the circular ring, an upwardly convex general support preferably having a part-spherical shape. The support is adjusted to a suitable height for supporting the plate means to be welded. For welding upwardly concave plate means, an upwardly concave intermediate structure may be arranged, in the central support area, to support with its top the central area of the plate means.

The weldable edges of the metallic, preferably aluminium, plate and/or plate means are prepared by a form milling cutter that simultaneously cuts to shape both the root portion and the sides of the groove. Conveniently, a cylindrical disc cutter having a relatively large diameter can be used. It is important that the disc cutter moves along such a line and at such an angle to the plate/plate means that a weld root surface is produced which allows easy positioning of one plate/plate means against another with substantially no slot or gap between adjacent root surfaces. If irregularities occur, a slot or gap of about 1 mm between the root surface may be acceptable.

The invention also relates to a curved structure, e.g. a large spherical LNG-tank or the like, the plate sections of which are manufactured by using the method according to said one aspect of the invention. Further aspects of the invention are disclosed by the methods disclosed in claims 20 and 21.

An embodiment of the invention will be described by way of example only, with particular reference to the accompanying drawings, in which:

Figure 1 schematically illustrates manufacturing equipment for joining together substantially planar plates to form plate means or assemblies;

Figure 2 schematically illustrates manufacturing equipment for joining together curved or part-spherical plate assemblies;

Figure 3 schematically illustrates fastening and support equipment for welding together part-spherical plate means or assemblies; and

Figure 4 schematically illustrates accessories of a manipulator device.

In Figure 1 there is shown a production line for joining together substantially flat or plane plates to form plate means or assemblies, the production line including first and second downhand welding and manipulating devices at stations 1 and 3 and a plate assembly turnover device at station 2. At station 1, plane plates 4 and 5, already cut to a desired, slightly tapered shape, are joined together by welding to form a plate assembly. The edges 6 and 7 of the plates 5 and 4, respectively, which are to be welded together have been machined by a cylindrical cutter to form a weld groove with root surfaces. A welding device 9 is mounted on an overhead cross beam 8 of a portal frame for movement transversely of the direction of the production line. The cross beam 8 is inclined at an angle of from 4° to 7°, typically 5°. This inclination is adjustable and the cross beam can be locked in its inclined position so that the weld groove is upwardly inclined in the direction of welding.

A suction fastening device (not shown in detail) is arranged beneath the cross beam 8 for holding the plates 4 and 5 firmly in place during welding. The suction fastening device is also inclined or tilted so that the weld groove between the edges to be welded together is parallel to the cross beam 8 of the portal frame during welding. Other parts of the welding equipment are shown in more detail in Figure 4 described hereinafter.

In order to weld both sides of the plate assembly, the latter, after being downhand welded at station 1, is turned upside down in station 2 and is passed to station 3. The second welding and manipulating device at station 3 includes a cross beam 8a of a portal frame 8 and a downhand welding device 9a each of the same kind as at station 1. Instead of welding the second side of the plane

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plates 4 and 5 at station 3, it is also possible to exclude station 3 and to weld both sides of the plate assembly 4, 5 at station 1, e.g. by returning the plate assembly to station 1 after turning the plate assembly upside down in station 2.

Figure 2 shows three embodiments 12a, 12b and 12c of a tiltable welding table including plate assembly support and fastening equipment (shown in more detail in Figure 3) The table 12a is used to weld together a first plate assembly, consisting of the two welded together plates 4 and 5, which has conveniently been cut to shape and then bent into a part-spherical shape and a similar second plate assembly consisting of welded together plates 14 and 15 and also having conveniently been cut to shape and then bent into a part-spherical shape. The edges of the plate assemblies to be joined together may be cut to shape, e.g. bevelled with a milling cutter. To enable welding of these edges, a welding device 17 is carried by a manipulator device 16 which allows movement of the welding device 17 in mutually exclusive directions perpendicular to each other. In particular, the manipulator device 16 comprises a horizontal beam 20 along which the welding device can move horizontally, a pillar 19 carrying the beam 20 for vertical movement of the latter and horizontal guides 18a and 18b for horizontal movement of the pillar 19. The plate assembly formed of the plates 4, 5, 14 and 15 is placed on the table 12a which is tiltable at least ± 20°, preferably at least ± 30°, from its horizontal position.

The plate assembly 4, 5, 14 and 15 is releasably fixed on the table 12a by means of suction fastening equipment. The curved weld groove formed by plate assembly edges 21 and 22 is arranged to lie in a vertical plane parallel to the guides 18a and 18b. During welding the tilt or inclination of the table 12a is continuously adjusted about an axis perpendicular to this vertical plane so that welding always takes part in a portion of the curved weld groove inclined, for example, at an angle of from 4° to 7°, typically about 5°, upwards. In particular the orientation of the table 12a is adjusted during welding so that the tangent to the curved or arcuate weld groove at the welding location is inclined to the horizontal at an angle of from 4° to 7°. The pillar 19 moves along the guides 18a and 18b as welding progresses along the weld groove. Should there be a discrepancy in the parallelity between the guides 18a and 18b and the weld groove, correction is made by moving the welding device 17 on the beam 20. The distance of the welding device 17 from the welding groove is adjusted by moving the beam 20 vertically up and down the pillar 19.

The manipulator device 16 is preferably equipped with a device for removing weld smoke, with groove cleaning devices for cleaning the weld groove upstream of the welding device and with a milling device for removing the weld reinforcement so that the weld joint can be made flush with the surfaces of the joined together plate assemblies. It is also possible to provide quality monitoring devices for monitoring the quality of the weld joint.

The tiltable table 12b differs from the table 12a in that it has two cross-wise arranged tilting axes allowing tilting about perpendicular horizontal axes as indicated by arrows 11 and 13. The table 12b is intended in particular for supporting plate assemblies forming upper and lower "calottes" of a spherical tank having plate portions 23, 24, 25 and 26. The welding device 17b of the table 12b has the same degrees of movement as the device 17. However, the two tilting axes of the table 12b make it possible for all welds to be carried out without having to release the fixation of the workpiece.

The table 12c is an alternative to the table 12a, the pieces to be welded on table 12c being intended to be welded by the welding device 17. Support and fastening means for holding the concave or convex side of a part-spherical workpiece are indicated by numerals 29, 30, 30b and 31b (see Figures 2 and 3). The main support member comprises a circular ring 29, the diameter of which may typically be about 10 m when manufacturing portions of a spherical tank having a diameter of about 40 m. At the centre of the support ring 29, there is a support 30, including a support member 30b which is used during welding the convex side of a plate assembly (see full lines in Figure 3). A corresponding lower support 30a is used when the concave side (see chain lines in Figure 3) of the plate assembly is to be welded. Vertically adjustable suction fastening devices 31a, 31b are used for pulling the plate assembly towards, and holding it against, the support ring 29. As an alternative to the central support structure 30a, 30b, another annular support, of smaller diameter than the ring 29, may be used. Such a support should also be vertically adjustable to conform to the concavity or convexity of the plates to be supported.

Figure 4 shows accessories of a welding device 9, for instance a high power MIG-welding device, using welding wire provided from a roll 32 for depositing weld metal into the welding groove at a welding location. In particular, there is provided a cleaning device in the form of a rotating brush 33 for cleaning the groove of impurities and harmful particles. Matter removed by the brush 33 is sucked into a pipe 34, in which an air flow is maintained for removing such matter. A groove sensor device 35 is arranged between the brush 33 and the welding device. A cutter 36 is provided for removing the weld reinforcement, formed during welding and extending above the surfaces of the plates welded together, the cutting chips being sucked away through a pipe 37. A similar suction pipe 38 removes weld smoke produced at the welding point 39.

The plate thickness of a spherical tank manufactured by the method described is, as a rule, between from 20 to 70 mm, thinner plates being used in the upper regions of the tank. The weld groove suitably includes double, symmetrically positioned V-grooves with root faces. The root area typically takes up from 40% to 50% of the plate thickness. The groove angle varies from approximately 90° for thinner plates to approximately 70° for

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thicker plates.

The invention is not restricted to the embodiments shown, but several modifications thereof are feasible within the scope of the ensuing claims.

Claims

1. A method of manufacturing a structure of welded together metallic, e.g. aluminium, plates (4,5), characterised in that two metallic plate means are supported on a tiltable support structure (12a) with two plate edges (21,22) of the plate means adjacent each other and defining a welding groove and in that the two plate edges are joined together by downhand welding involving moving a welding device (17) along said welding groove and tilting the support structure (12a) to provide a substantially constant inclination of the welding groove at the position of the welding device (17) as the latter is moved along the welding groove.

2. A method according to claim 1 for creating a curved structure, characterised in that the two plate means are bent prior to being joined together and in that the said welding groove is curved with a changing inclination along its length.

3. A method according to claim 1, characterised in that each plate means is formed by welding together substantially flat metallic plates (4,5) by downhand welding using welding means (9,9a) moving along a weld groove.

4. A method according to claim 3, characterised in that, prior to joining said plate edges together, each plate means is bent into a curved form so that the plate means have curved plate edges and said welding groove is curved with a changing inclination along it length.

5. A method according to claim 4, characterised in that each of the plate means (4,5;14,15) is cut to a desired shape before being bent into its curved form.

6. A method according to any of claims 3 to 5, characterised in that said downhand welding together of said plates is performed by said welding means (9,9a) being movably mounted on an overhead transverse frame (8) having an adjustable inclination.

7. A method according to any of claims 3 to 6, characterised in that prior to welding the plates together to form each plate means, said weld groove between the plates is cleaned by brushing.

8. A method according to claim 7, characterised in that said brushing is provided by a brushing device (33) which moves along the weld groove in front of said welding means (9), preferably at a distance of about half a metre from the welding means.

9. A method according to any of the preceding claims, characterised in that after welding the plates together to form said plate means the welds so created are milled to remove weld reinforcements.

10. A method according to claim 9, characterised in that the milling is provided by a milling cutter (36) moving in the direction of the weld behind the welding means (9).

11. A method according to any of claims 3 to 10, characterised in that each plate means (4,5) is formed by welding said plates together in one pass on one side, turning the plate means over and welding the plates in one pass on the other side.

12. A method according to any of claims 3 to 11, characterised in that in the formation of each plate means a suction fastening device holds the plates and is tilted so that the weld groove at the welding point is orientated upwards relative to horizontal plane at an angle of from 4° to 7°, preferably about 5°, in the welding direction.

13. A method according to any of the preceding claims, characterised in that said plate edges (21,22) are cut, e.g. machined, prior to being joined together to enable formation of an accurate welding groove.

14. A method according to any of the preceding claims, characterised in that said tiltable support structure (12a) includes a tiltable table carrying the plate means to be welded together and which is tilted during welding so as to orientate the welding groove between the plate edges being welded together at the welding point to an upwards inclination of from 4° to 7°, preferably about 5°, in the direction of welding.

15. A method according to claim 2, 4, 5 or any of claims 6 to 13 when dependent on any of claims 2, 4 or 5, characterised in that the plate means are supported on the tiltable table by an annular member (29) allowing support of either a convex side or a concave side of the plate means.

16. A method according to claim 15, characterised in that an additional support structure (30a,30b) is provided centrally of the annular support member (29) and includes means for adjusting its height position.

17. A method according to any of the preceding claims, characterised in that, prior to joining the plate means

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together, the edges of the plate means to be welded are finished to create said plate edges by removing the machining allowance by a form milling cutter, which simultaneously forms edges for providing both the root surface of the weld and the sides of the welding groove.

18. A method according to any of claims 1 to 16, characterised in that the said plate edges are bevelled.

19. A large, spherical LNG-tank or the like, characterised in that it is assembled of plate means each manufactured according to the method of any of the preceding claims.

20. A method for manufacturing a large basically spherical vessel from plate aluminum plates having a thickness in the range of from about 20 mm to about 70 mm, comprising:

(a) forming at least first and second plane plate assemblies by downhand welding together plane plates controlled by a welding device including an adjustably lockable portal;

(b) cutting each welded plane plate assembly to a peripheral shape that fits into the structural pattern of the vessel except for an allowance for machining in step (d);

(c) bending each plate assembly to a part-spherical configuration;

(d) machining respective edges of the first and second bent plate assemblies to a profile suitable for welding in step (e); and

(e) downhand welding the first and second plate assemblies together along the machined edges using a manipulator device that includes a tiltable support.

21. A method for manufacturing a large spherically curved structure from plane aluminum plates having a thickness in the range of from about 20 mm to about 70 mm, comprising:

(a)

(i) forming a first plane plate assembly by positioning two plane plates to meet in edge-to-edge relationship along a line that is inclined to the horizontal and downhand welding together the plane plates in an upward direction along the line at which they meet;

(ii) forming a second plane plate assembly by positioning two further plane plates to meet in edge-to-edge relationship along a line that is inclined to the horizontal and downhand welding together said further plane plates in an upward direction along the line at which they meet;

(b) cutting each plane plate assembly to a peripheral shape that fits into the structural pattern of the spherically curved structure except for an allowance for machining in step (d);

(c) bending each plane plate assembly to a part-spherical configuration;

(d) machining respective edges of the first and second bent plate assemblies to a profile suitable for welding in step (f);

(e) positioning the first and second bent plate assemblies to meet at their machined edges along an arcuate line that extends upward from a first end of the line in a direction toward a second end of the arcuate line; and

(f) downhand welding the first and second bent plate assemblies together in said direction along the arcuate line from the first end of the arcuate line to the second end thereof, whereby the location of welding advances along the arcuate line, while adjusting the orientation of the bent plate assemblies such that as the location of welding changes, the tangent to the arcuate line at the location of welding remains inclined to the horizontal.

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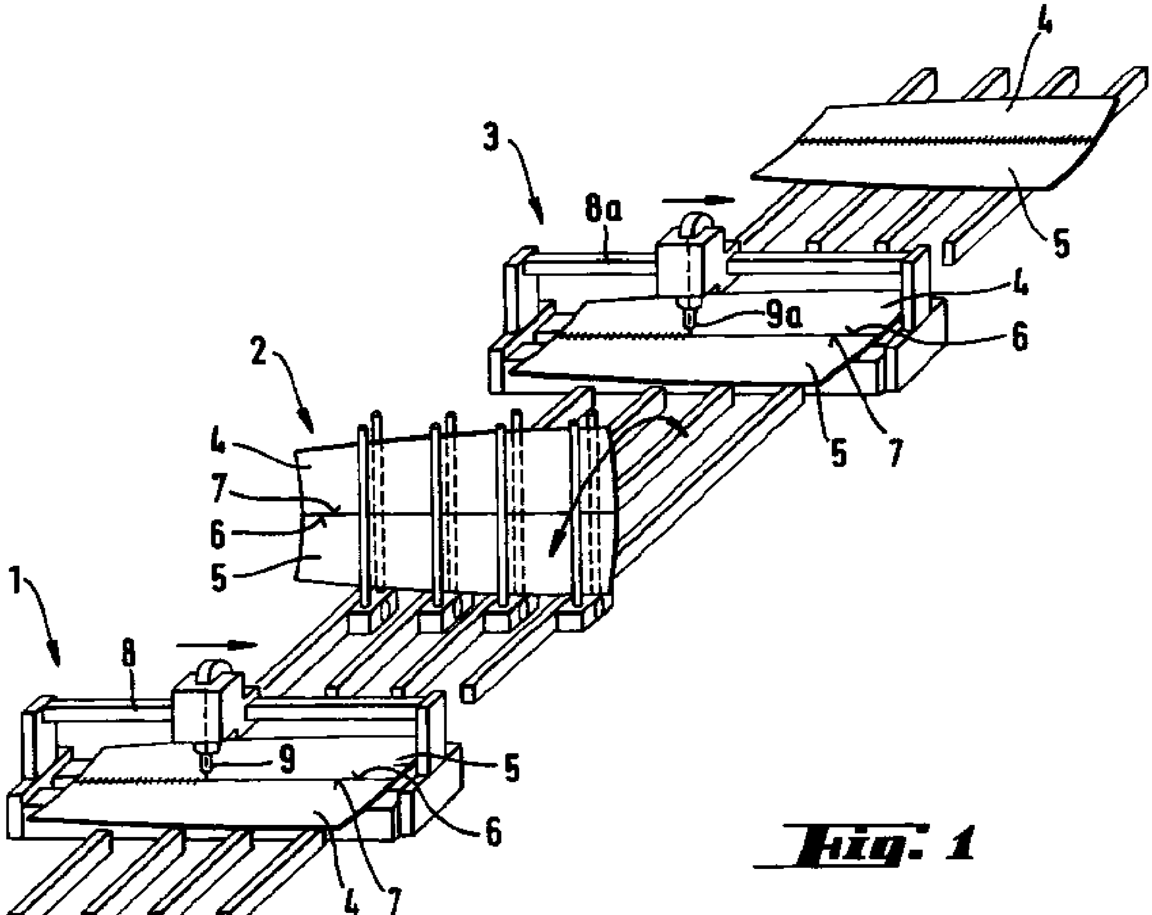

Fig. 1

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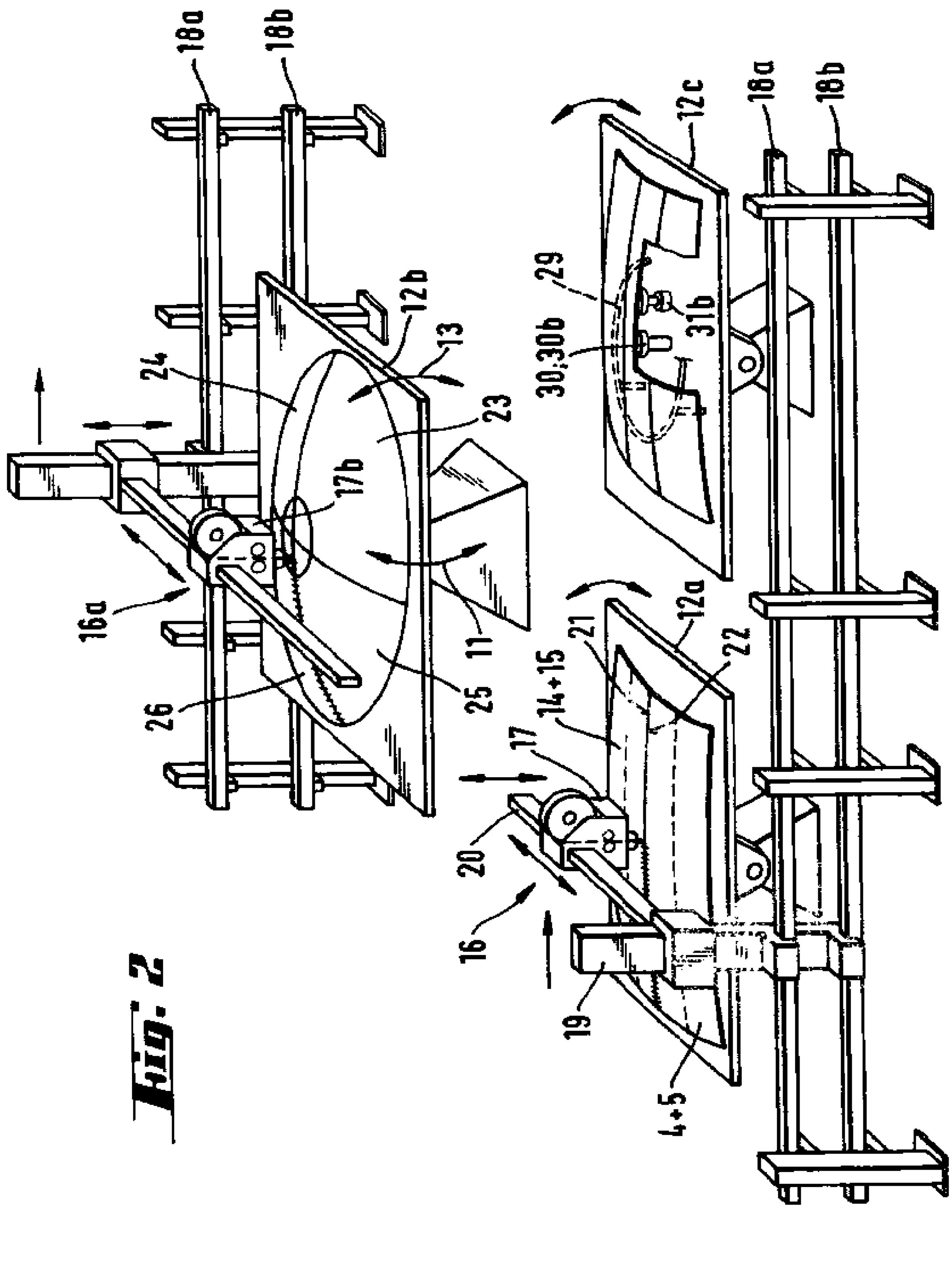

Fig. 2

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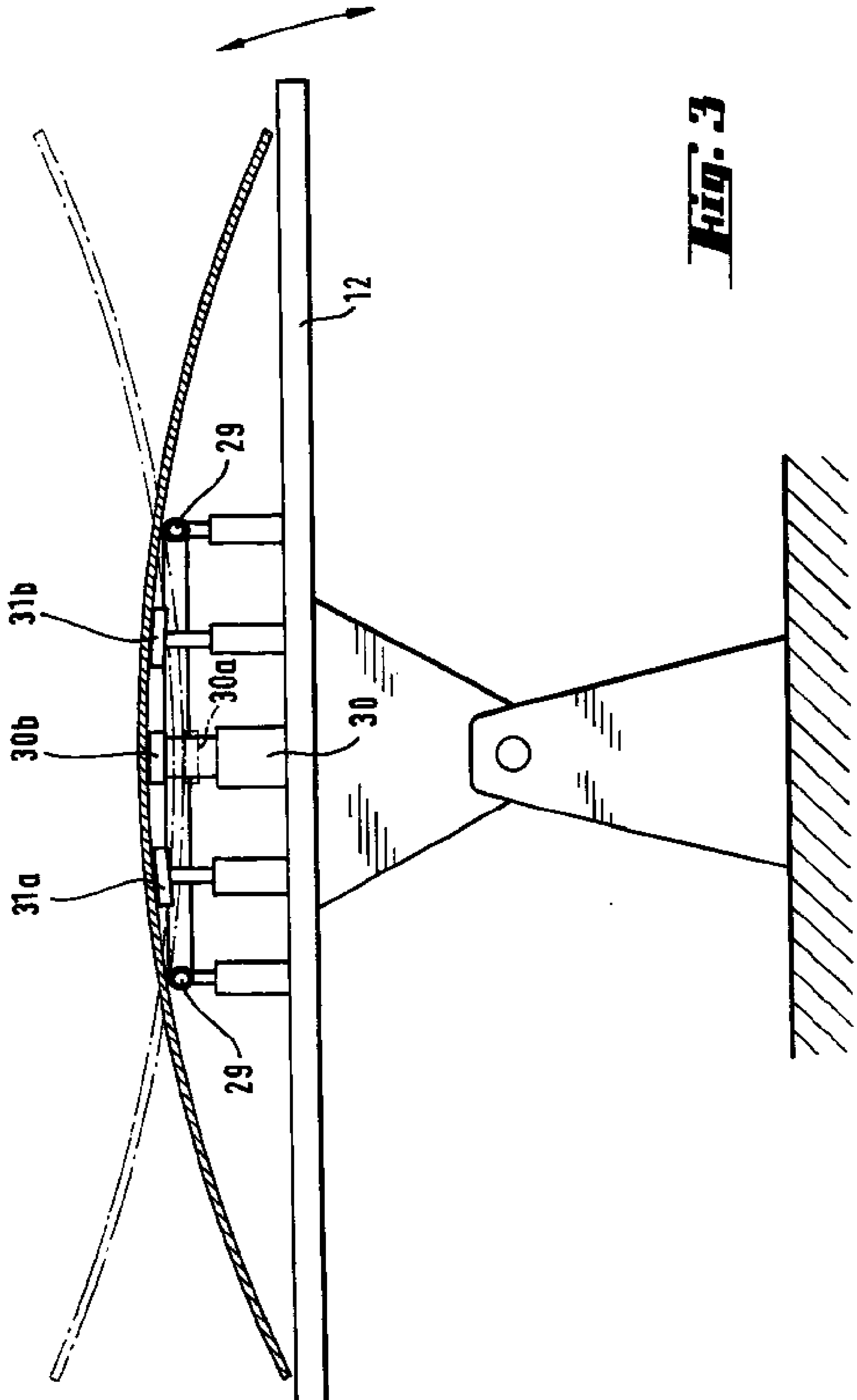

Fig. 3

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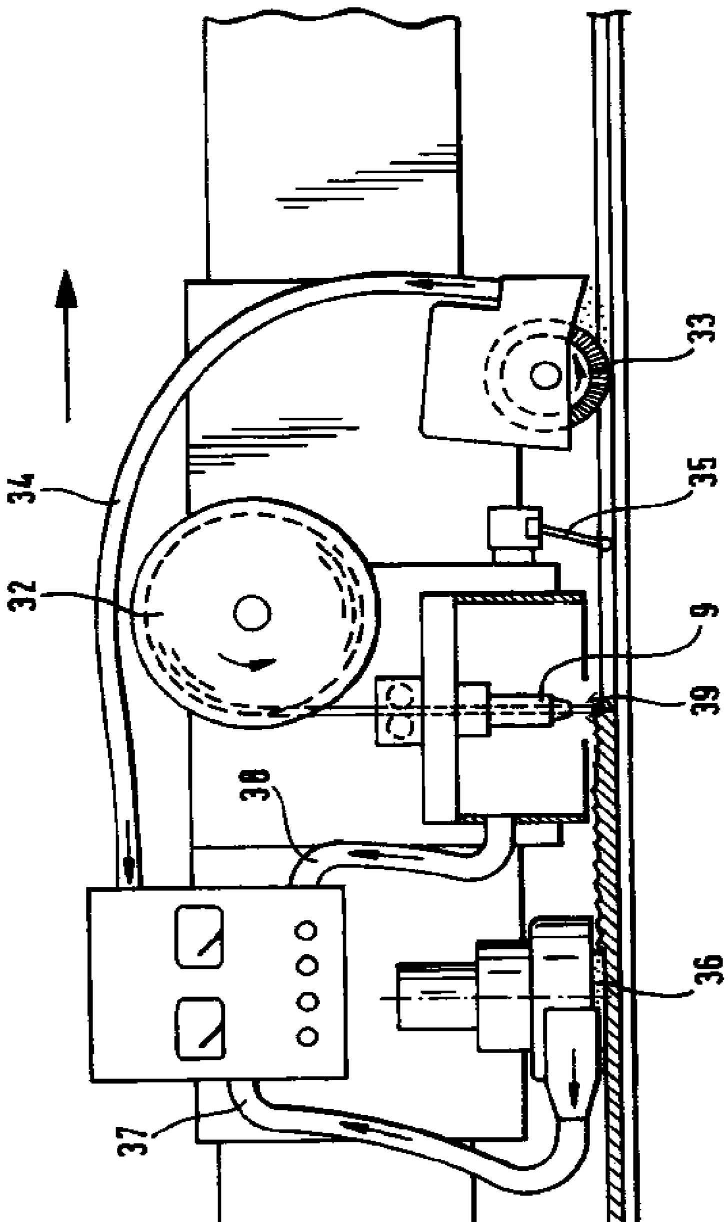

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 95 30 4578

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP-A-0 092 533 (PALMER, LENNART) * page 1, line 1 - page 2, line 24; claims 1-7; figures 1-3 * ---	1,2,4, 12,14, 19-21	B23K37/04 B23Q3/06
A	US-A-5 307 979 (JONG-HEE KIM) * abstract; figures 1-12 * ---	1,2, 4-11,13, 17-21	
A	US-A-5 010 226 (KAZUHIRO SATO ET AL.) * abstract; figures 1-7 * ---	1,2,4, 11,12, 14,19-21	
A,D	EP-A-0 570 212 (KVARERNER MASA-YARDS OY) * abstract; figures 1-4 * ---	1,3,5, 19-21	
A	US-A-4 832 322 (RONALD E. CHRISTENSON) * abstract; figures 1-10 * ---	1,2,4-6, 11,14, 19-21	TECHNICAL FIELDS SEARCHED (Int.Cl.6) B23K B23Q B25B B63B
A	FR-A-2 495 734 (FRAMATOME) * claims 1-5; figures 1-3 * ---	1,14,15	
A	PATENT ABSTRACTS OF JAPAN vol. 6 no. 97 (M-134) ,5 June 1982 & JP-A-57 032896 (MITSUBISHI HEAVY IND LTD) 22 February 1982, * abstract * ---	1,4, 14-16	
A	FR-A-2 673 554 (APPLICATIONS ET UTILISATIONS DES PROPRIETES ELECTRIQUES DES MATERIAUX) * abstract; figures 1-9 * -----	1,14,15	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	22 September 1995	Cuny, J-M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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